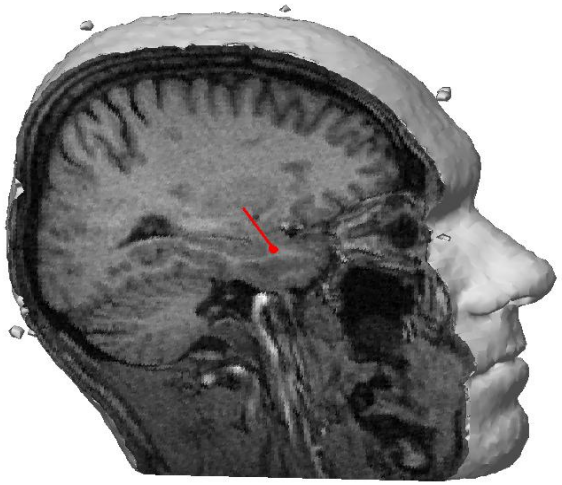
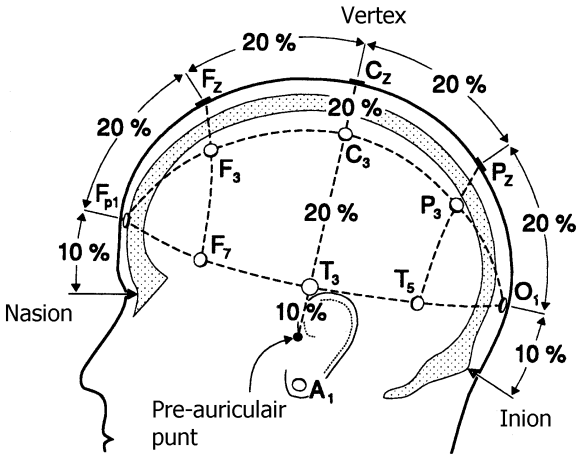
EEG source imaging
Challenges and trends

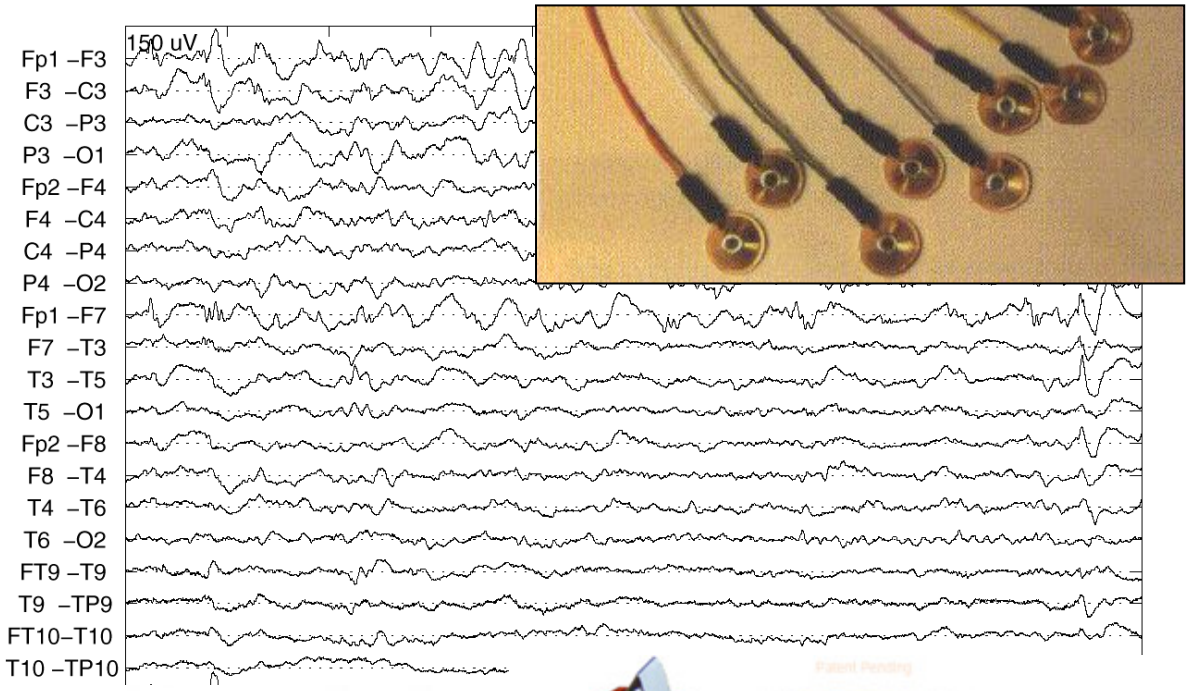
Dr. ir. Hans Hallez



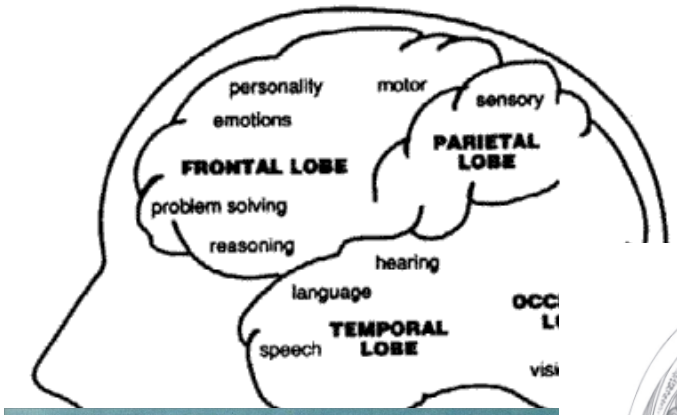
Electrophysiology Workshop 04/10/11

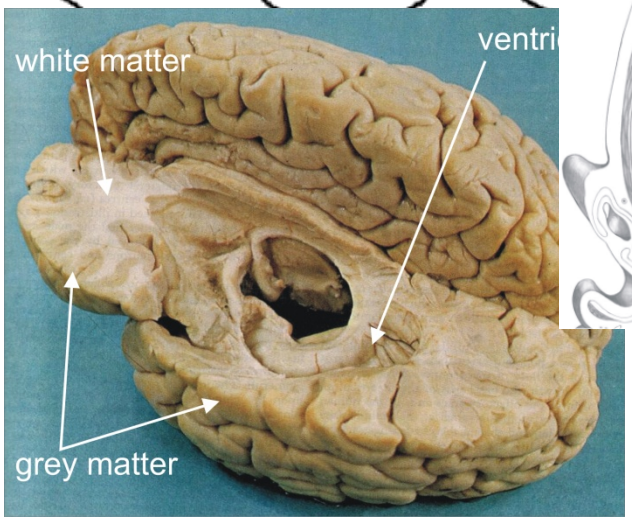
Introduction: Electroencephalography

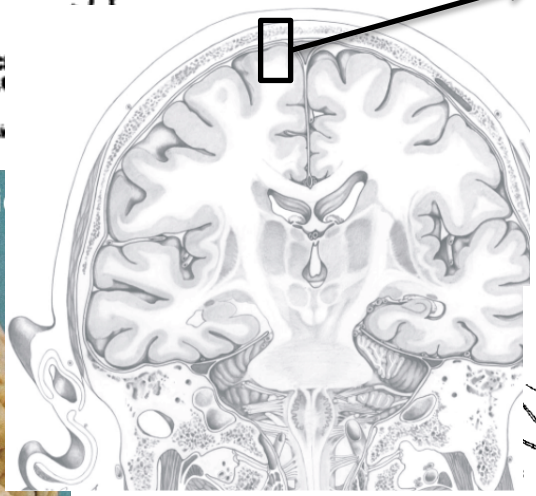




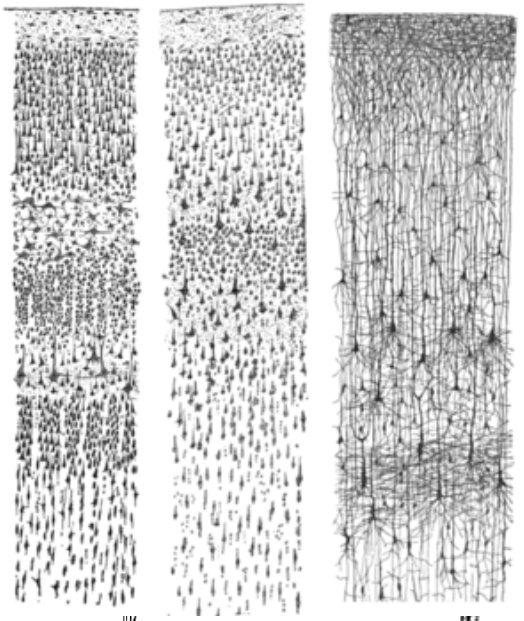
Introduction: Generators of the EEG

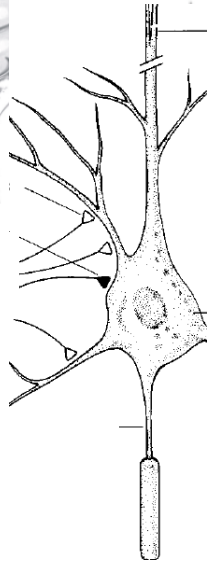


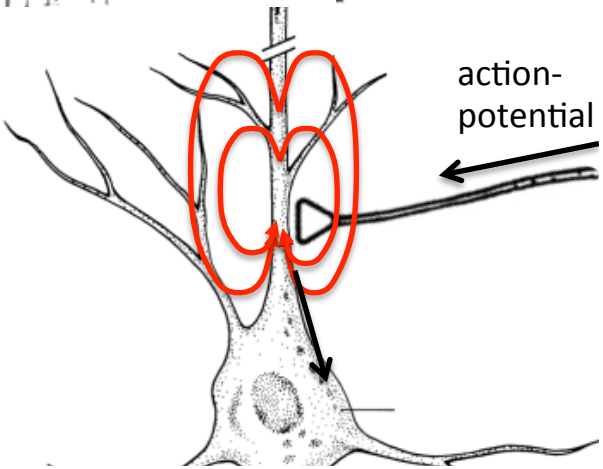




Grey matter

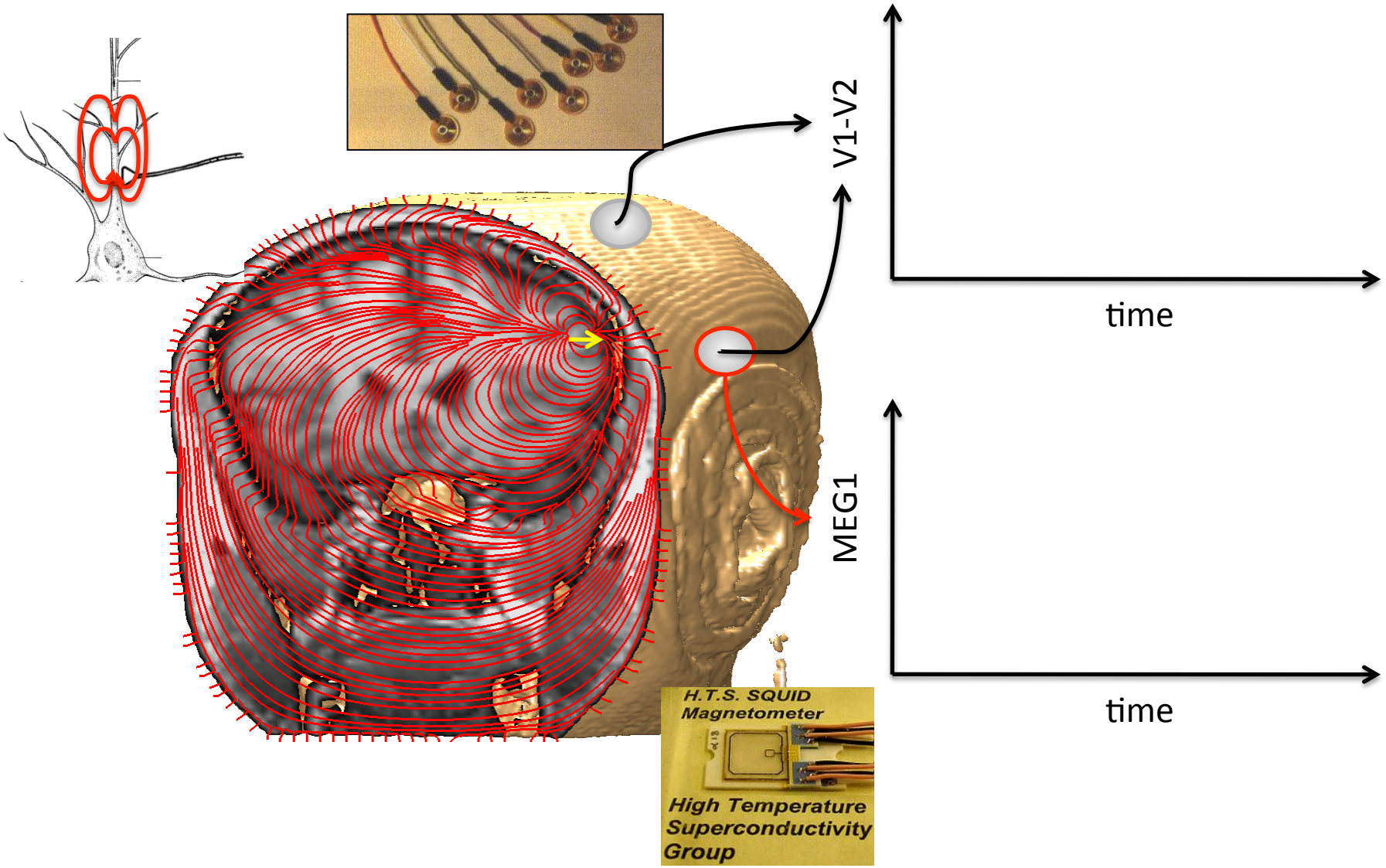






Excitatory post-synaptic potential (EPSP)

Background: Generators of the EEG

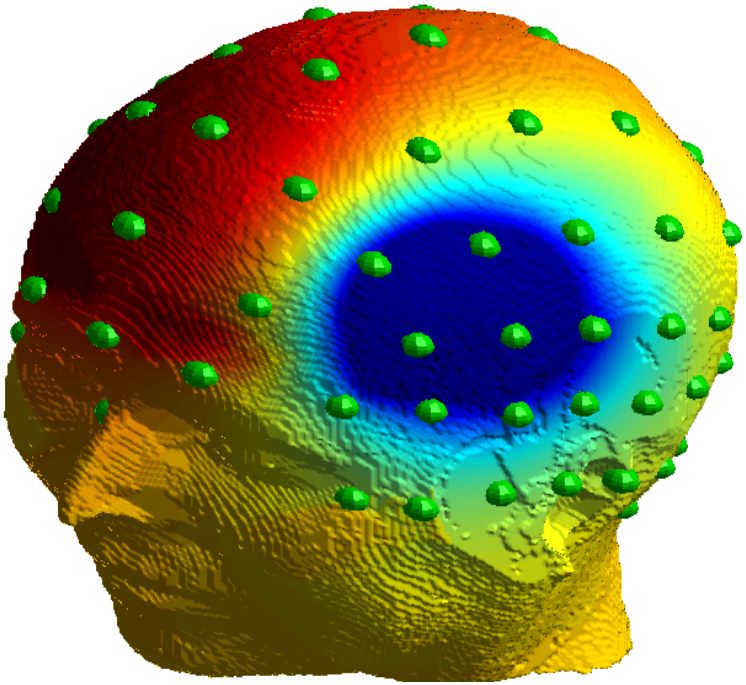


Content

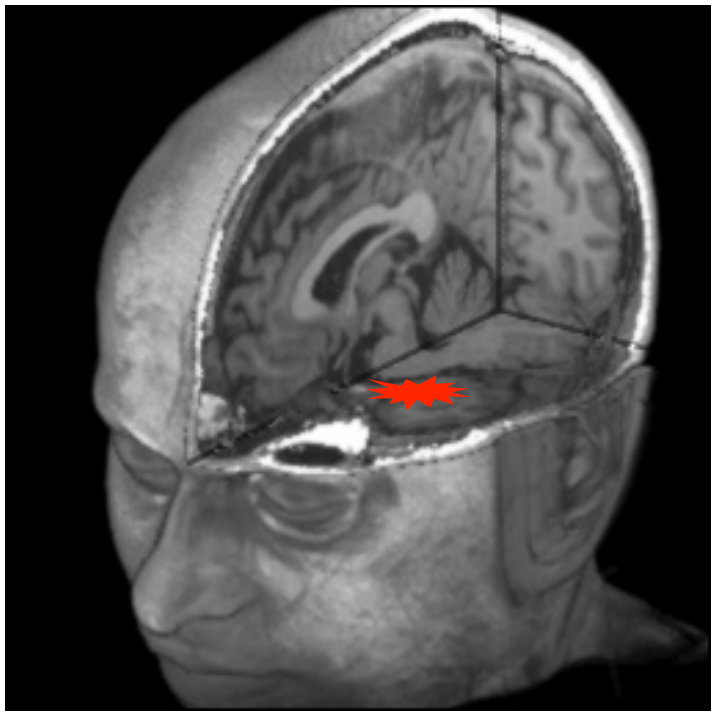
- Introduction
- Accurate forward modeling en conductivity uncertainty
- Illposedness and sensitivity to noisy data
- Conclusions

Introduction: EEG source localization

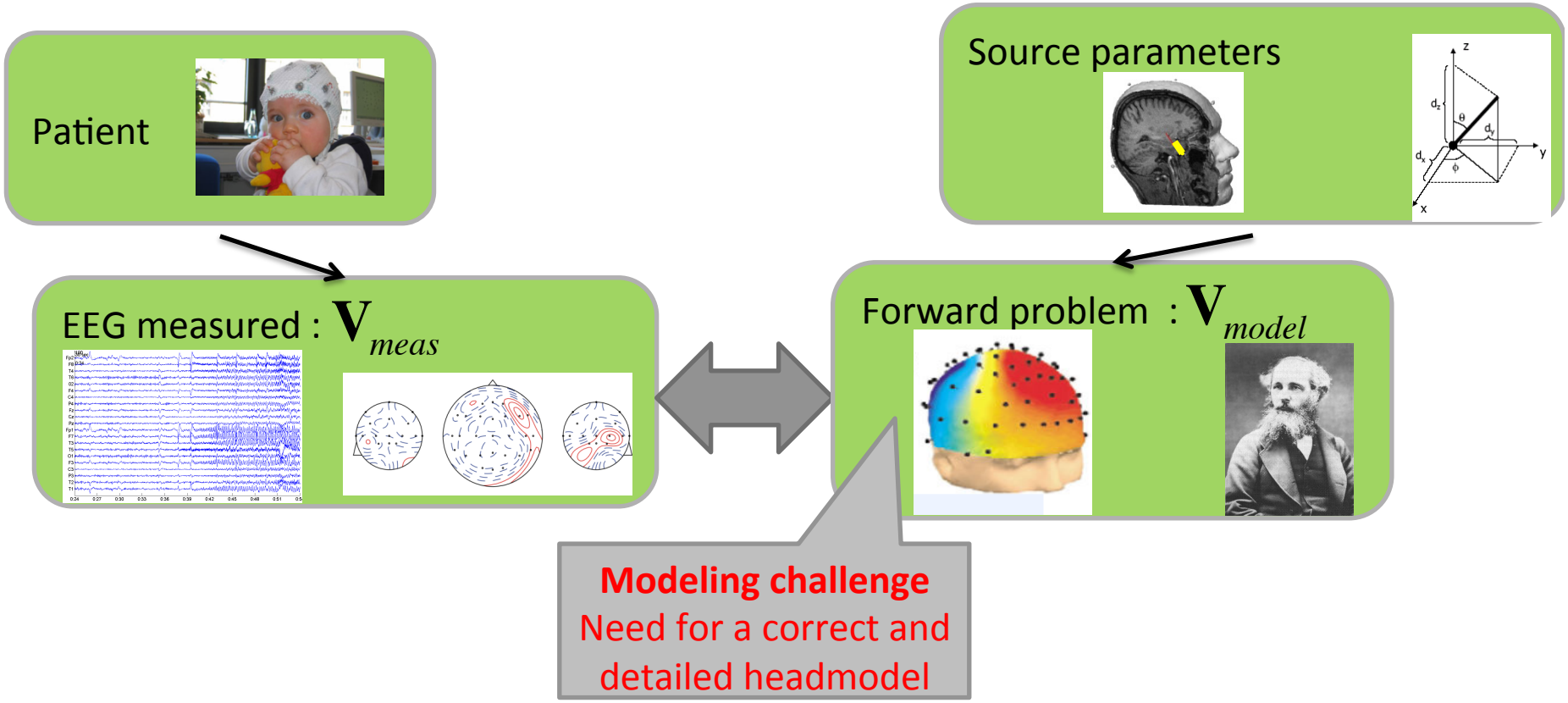
Potential distribution at the scalp measured at electrodes or sensors



Estimation of the origin of the electrical activity in the brain



Introduction: EEG source localization

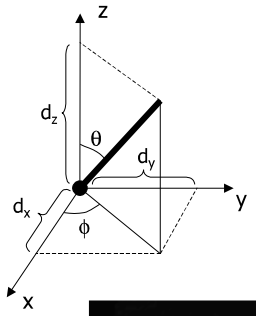


Estimation of the parameters by means of minimization of a cost function

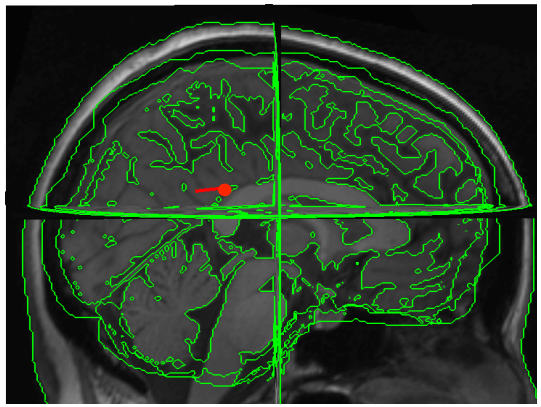
$$RE = \left\| \mathbf{V}_{meas} - \mathbf{V}_{model} \right\|$$

Introduction: EEG source localization

Assumption : Within the EEG time frame there is only one source

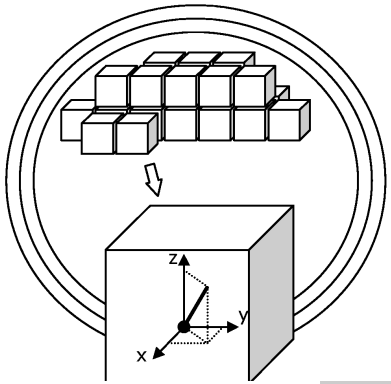


Single dipole model

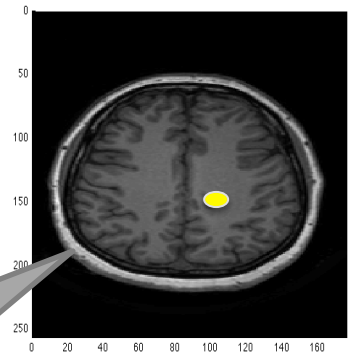


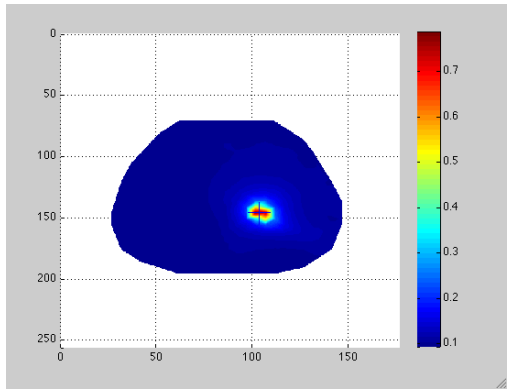
Parametric solution

Assumption : there are many sources



Distributed source model





Imaging solution
MNE, (s)LORETA, FOCUSS, beamformers

Illposedness challenge
Need for the correct number of sources
Sensitive to noisy data

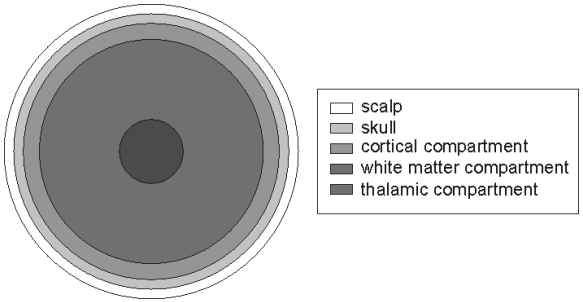
Content

- Introduction
- Accurate forward modeling en conductivity uncertainty
- Illposedness and sensitivity to noisy data
- Conclusions

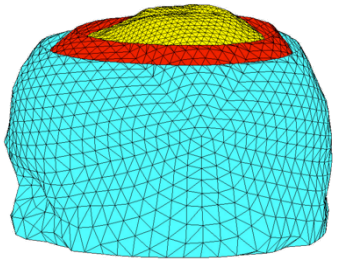
Challenge: Forward Modelling

- Geometry is a key aspect in EEG source imaging

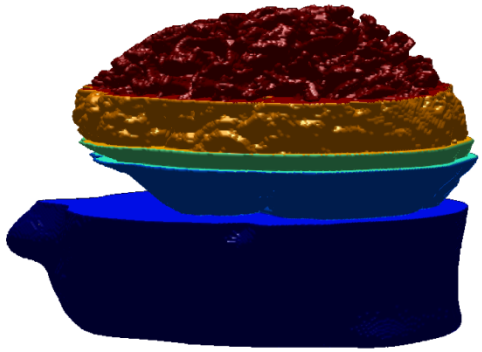
Spherical head models



Surface head models



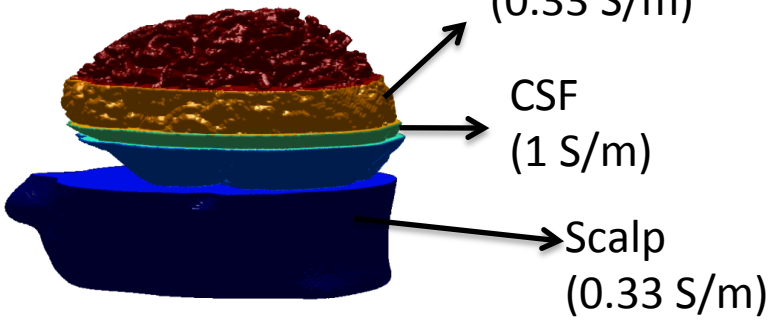
Volume conductor models



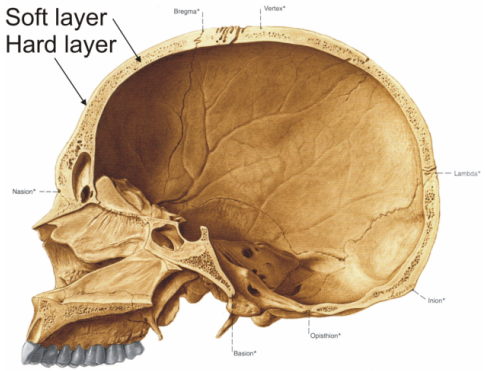
Segmentation of different modalities (MRI, CT)

Challenge: Forward Modelling

- EEG source imaging is highly sensitive to the conductivity

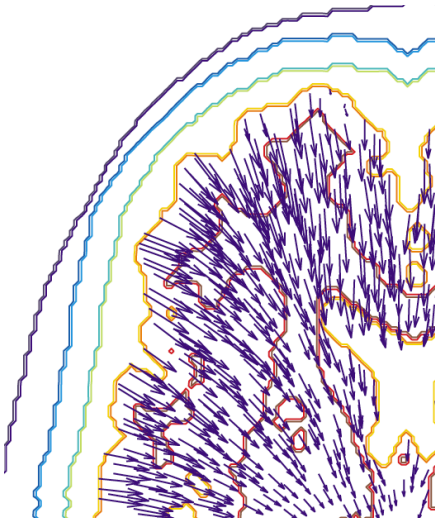


Skull

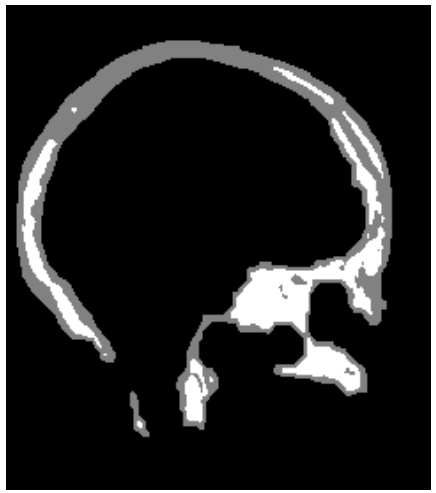


- Variable conductivity
- Inhomogeneous

Uncertainty in conductivity value causes shifts in source estimate



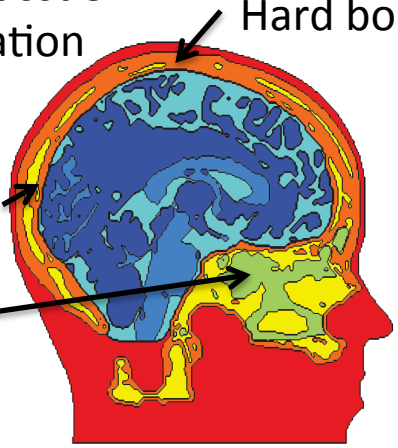
Skull can be seen as a layered model

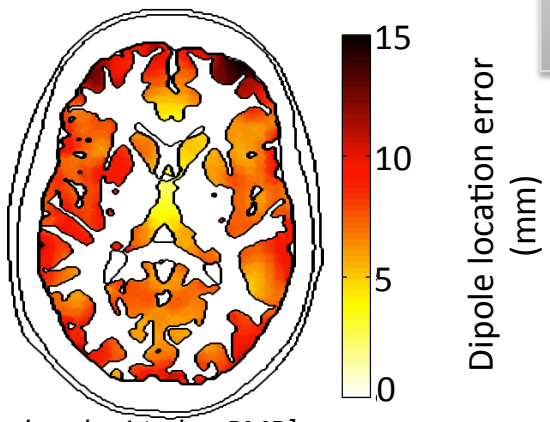


Trend: Forward modeling

- Highly detailed head modeling

Detailed tissue segmentation modeling

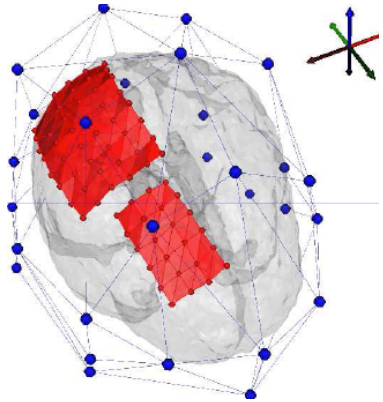


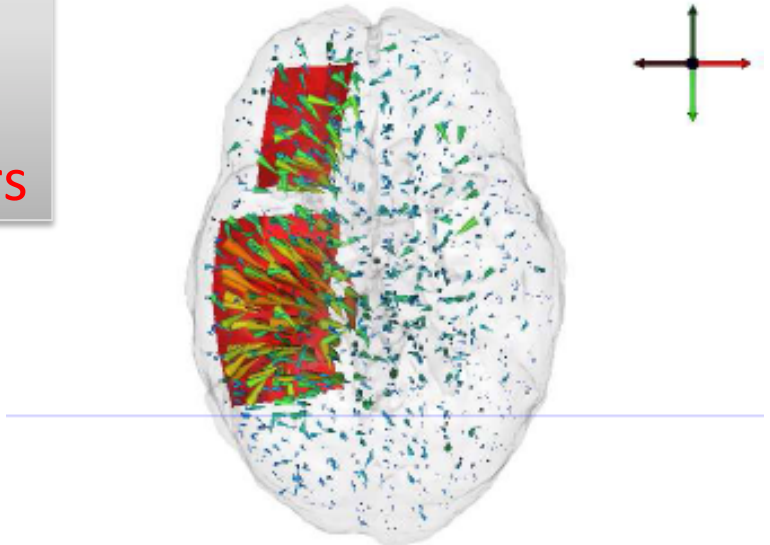


[Montes et al., submitted to PMB]

Need for fast and stable forward solvers

Cortical grid modeling during simultaneous EEG and ECoG registration





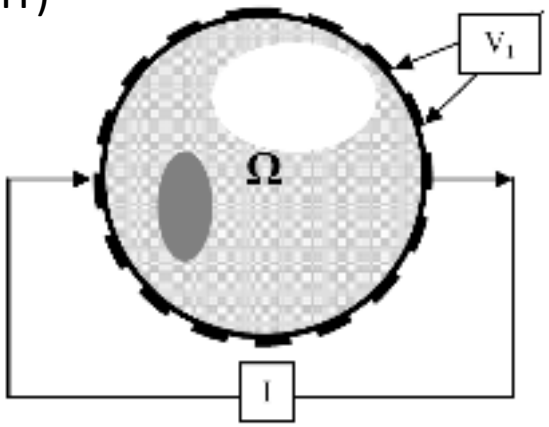
[Lanfer and Wolters et al., in preparation]

Trend: Forward modeling

- Advanced measurements and algorithms

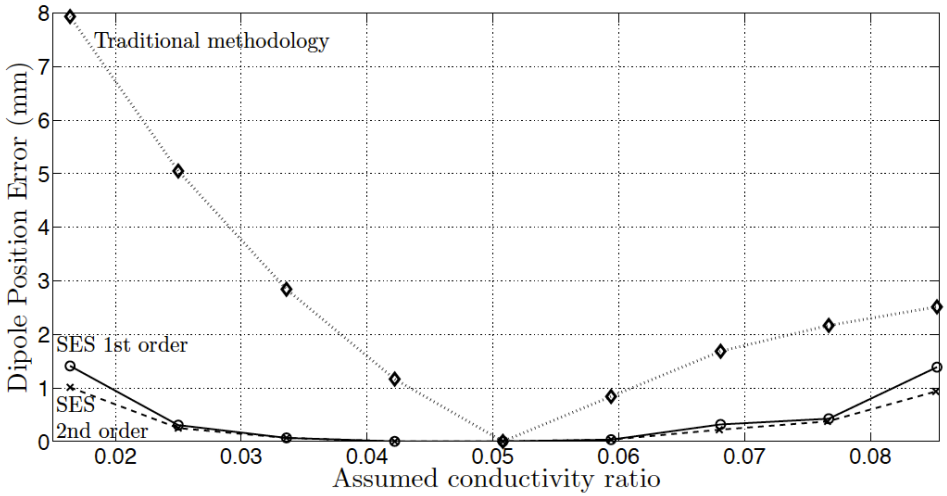
Measuring conductivity in individual patients

Electrical Impedance Tomography (EIT)



Magnetic Resonance - EIT

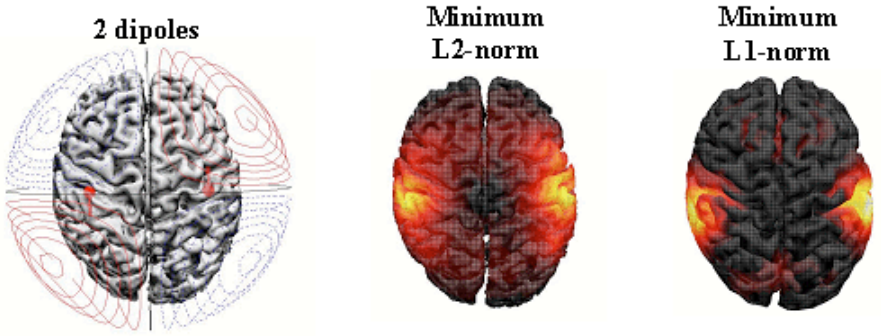
Reducing conductivity uncertainty based on subselection of electrodes during EEG source estimation procedure



[Crevecoeur et al., Patent WO 2011/058059A1]

Challenge: Tackling illposedness

- Illposedness
  - Different source combinations give rise to same EEG
  - Number of sources is unknown
  - Data contains noise



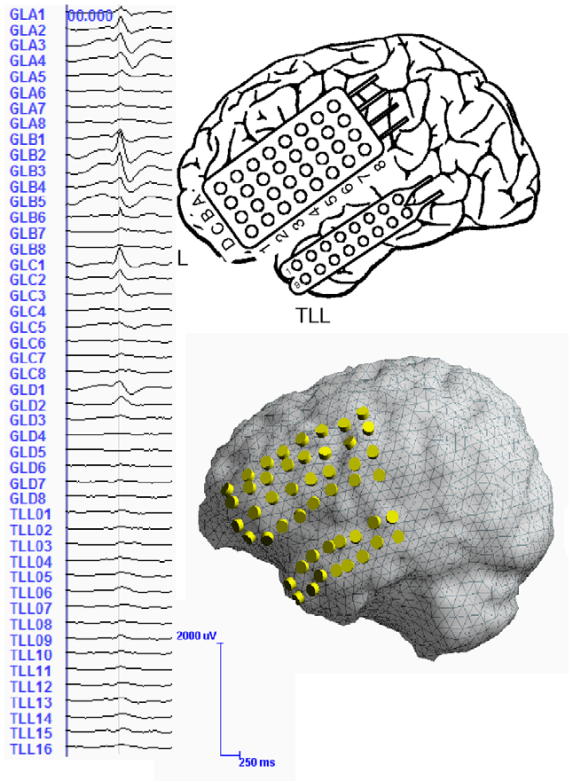
- Source estimation only based on EEG is not enough

Trends: EEG/i(nvasive)EEG source imaging

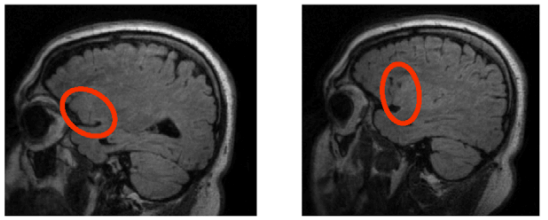
- Possibility of implantation is growing
  - Invasive recording are less noisy

Case study: Localization of left frontal spikes

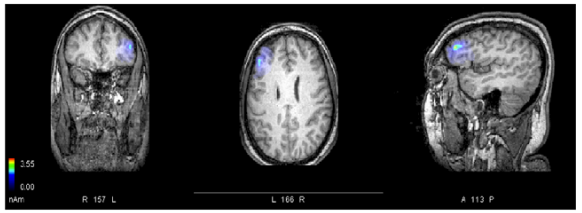
(a) Spike average and schematic electrode positions



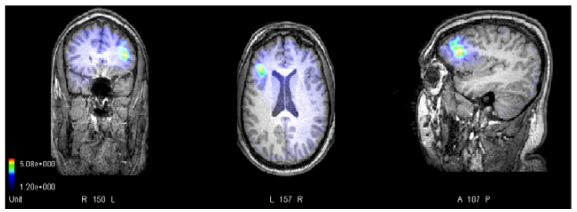
(b) Sagital Flair MRI showing areas with signal increase



(c) Linear estimation



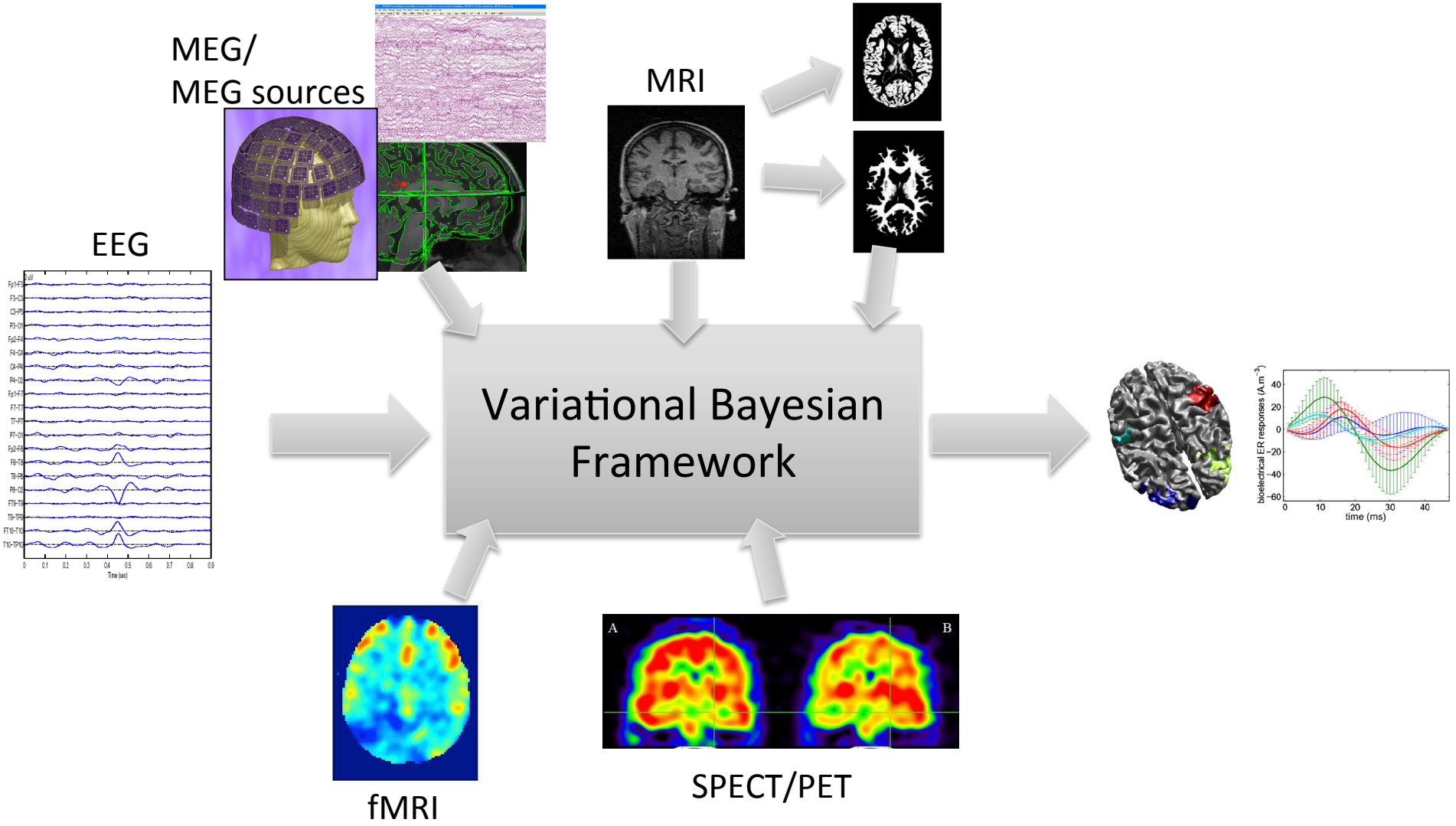
(d) MUSIC



[Dümpelmann et al., 2009]

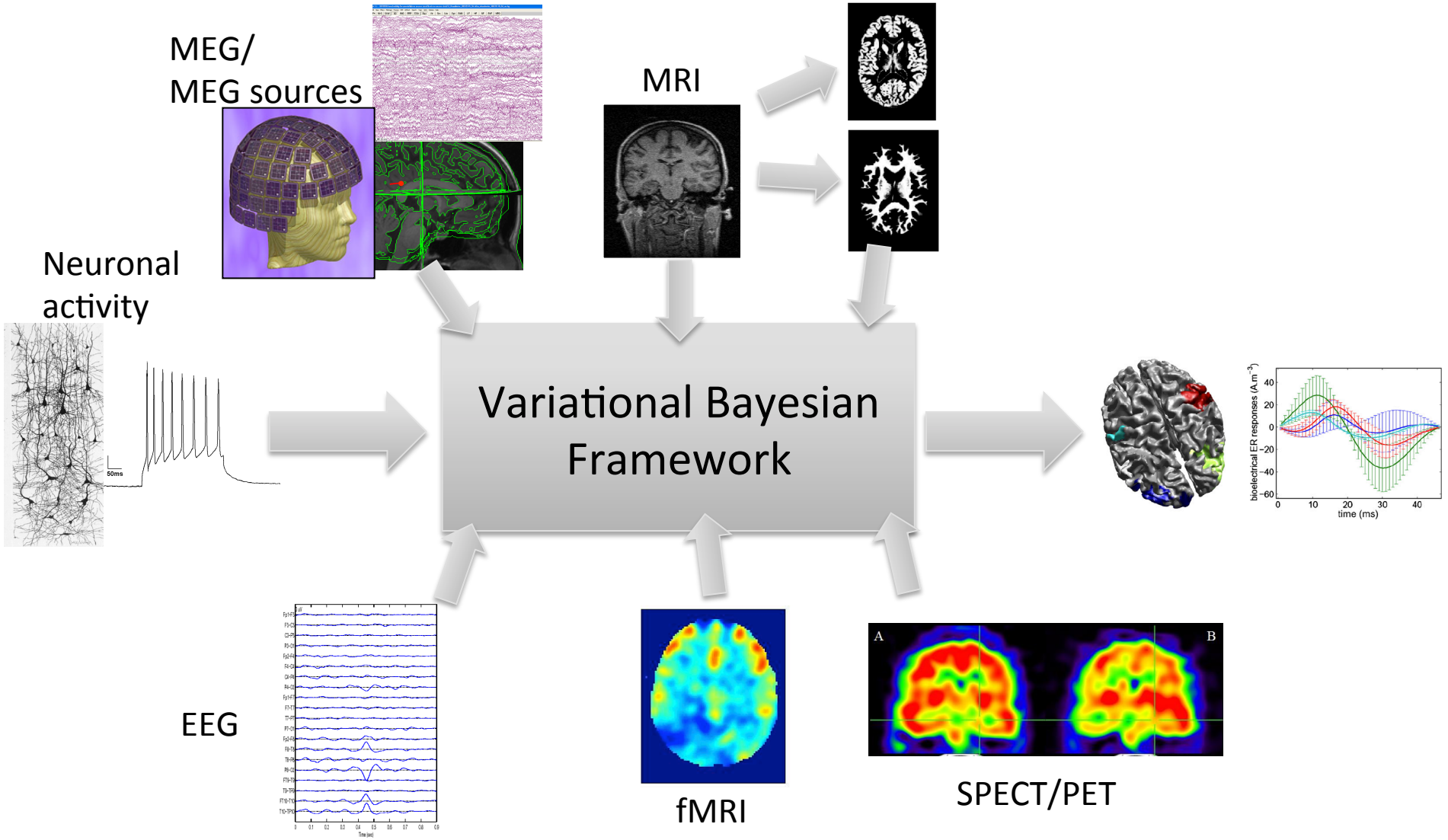
Trends: Multimodality Imaging

- Integrating multiple modalities in EEG source imaging



Trends: Multimodality Imaging

- Integrating multiple modalities in EEG source imaging



Conclusions

- EEG source localization is method to estimate the source with a high temporal resolution

- But spatial resolution is poor due to
  - Forward modeling: geometry and conductivity
  - Illposedness: number of sources and noise

Conclusions

- Trends towards
  - Construction highly detailed models
  - Multimodal integration for neuronal activity estimation
  - Invasive recordings and simultaneous EEG/iEEG estimation
  - Advanced algorithms to decrease sensitivity to noise and uncertainty in the modeling parameters

Questions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